AL-TR-1992-0139

AD-A260 255

A R M S T R O N G

L A B O R A T O R Y

INDUSTRIAL HYGIENE EVALUATION OF F-111 FUEL TANK SEALANT PROCESS

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December 1992

Final Technical Report for Period January 1991 - October 1991

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
December 1992

3. REPORT TYPE AND DATES COVERED
Final January 1991 - October 1991

4. TITLE AND SUBTITLE
Industrial Hygiene Evaluation of F-111 Fuel Tank Sealant Process

5. FUNDING NUMBERS

6. AUTHOR(S)
Robert Walton

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Armstrong Laboratory
Occupational and Environmental Health Directorate
2402 E Drive
Brooks Air Force Base, TX 78235-5114

8. PERFORMING ORGANIZATION REPORT NUMBER
AL-TR-1992-0139

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report presents an informative, inclusive and concise evaluation of a new tank sealant process. Recommendations are made based on air sampling results and current industrial hygiene practices. This report will aid those bases implementing this new process in selecting the proper protective equipment for workers and in determining where and what to sample for when documenting worker exposure.

14. SUBJECT TERMS
Fuel Tank Sealant Process

15. NUMBER OF PAGES
38

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
298-102

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INDUSTRIAL HYGIENE EVALUATION OF F-111 FUEL TANK SEALANT PROCESS

INTRODUCTION

Purpose and Scope

In response to a 12 Oct 90 letter of request from the McClellan Air Force Base (AFB) Bioenvironmental Engineering Section (BES), we conducted an initial industrial hygiene evaluation of this new sealant process. Three separate surveys (22-26 January 1991, 12-16 August 1991, and 29-31 October 1991) were performed at McClellan AFB during actual spray sealant operations. Additional air sample results included in this report were done by Lt Devine of BES during September and October 1991. The purpose of the surveys was to conduct a thorough industrial hygiene evaluation of this new fuel tank sealant process. The ultimate goal was to determine how the process could be safely implemented and to provide that documentation to other Air Force Materiel Command (AFMC) bases.

Background

The F-111 fuel tank sealant process is new to the Air Force but has been used successfully by civilian industry for some time. The F-111 has had a history of fuel tank leak problems and therefore was a good candidate for testing the new sealant process.

Description of Operation

The process consists of a number of different operations which must be performed in a certain order. It begins with fuel tank de-sealing where all the old sealant is removed by waterpicking. The old sealant surface is prepped using a wire brush and wiped down with Turco 6628. The sealant surface is then primed with a Desoto epoxy primer which takes 30 to 60 minutes, depending on tank size, when using a spray gun (air pressure @ 30 $\pm$ 5 psi and fluid pressure @ 4 $\pm$ 1 psi). The primer coat requires a 30-minute to 45-minute drying time prior to sealant application. The sealant application requires two coats to ensure proper coverage. By applying white and black coats separately, sealant coverage for each coat can be easily determined by visual inspection. The sealant is also applied with an air-assisted airless spray gun (fluid pressure is 500 psi @ pump but decreases to 30 psi @ gun tip); each application requires between 1.5 to 3 hours per coat depending on tank size. The current procedure requires a 3-hour drying time between sealant coat applications. During spray application, the tank is

ventilated by two supply hoses and two exhaust hoses to control the explosive hazard. After the spray application is finished, the tank should be continuously vented by one exhaust hose for a period of 7 days to control the solvent off-gassing during drying. A technical order on sprayable sealant procedures is currently being drafted.

Methods

Standard National Institute for Occupational Safety and Health (NIOSH) Analytical Methods were used for the sampling and analyses of air contaminants except for isocyanates, 1-methoxy-2-propanol acetate (PM Acetate), and diethyltoluenediamine (DETDA). For these compounds, sampling and analyses were performed according to manufacturer-published methods; there is no published NIOSH method.

DISCUSSION

Findings

Ventilation: The first point that must be noted is that the F-111 fuel tank sealant process cannot be performed safely without the use of local supply and exhaust ventilation. The constituents which make up the primer, especially toluene and methyl ethyl ketone (MEK), present an extreme explosive hazard when sprayed in the confined space of the fuel tanks. Furthermore, the configuration of the tanks with multiple bays offers a challenge for eliminating concentration pockets even with local ventilation. Fortunately, we were able to overcome that problem with a dual push-pull system utilizing pre-existing openings within the fuel tanks. Figure 1 shows how the air is supplied at two locations from the middle top of the tank, while air is exhausted from the top at each end of the tank. The operation is currently being performed in Hangar 251 and utilizes an HDU-13 for supply air and a pre-existing overhead vehicle maintenance type exhaust system with a makeshift booster. The current system has adequately controlled the explosive atmosphere problem in the tank during spraying, but it has some other problems that MUST be addressed. The primer coating applied first to the tank has a consistency similar to paint and therefore has problems associated with local exhaust of painting operations. The most important consideration is the particulate aerosol formed by the overspray. The current system lacks a particulate filter, and the paint particles are being deposited within the ducting of the ventilation system. The accumulation of the paint particles presents fire and explosive hazards, especially when the booster system does not have intrinsically safe motors. Obviously, the booster system should contain

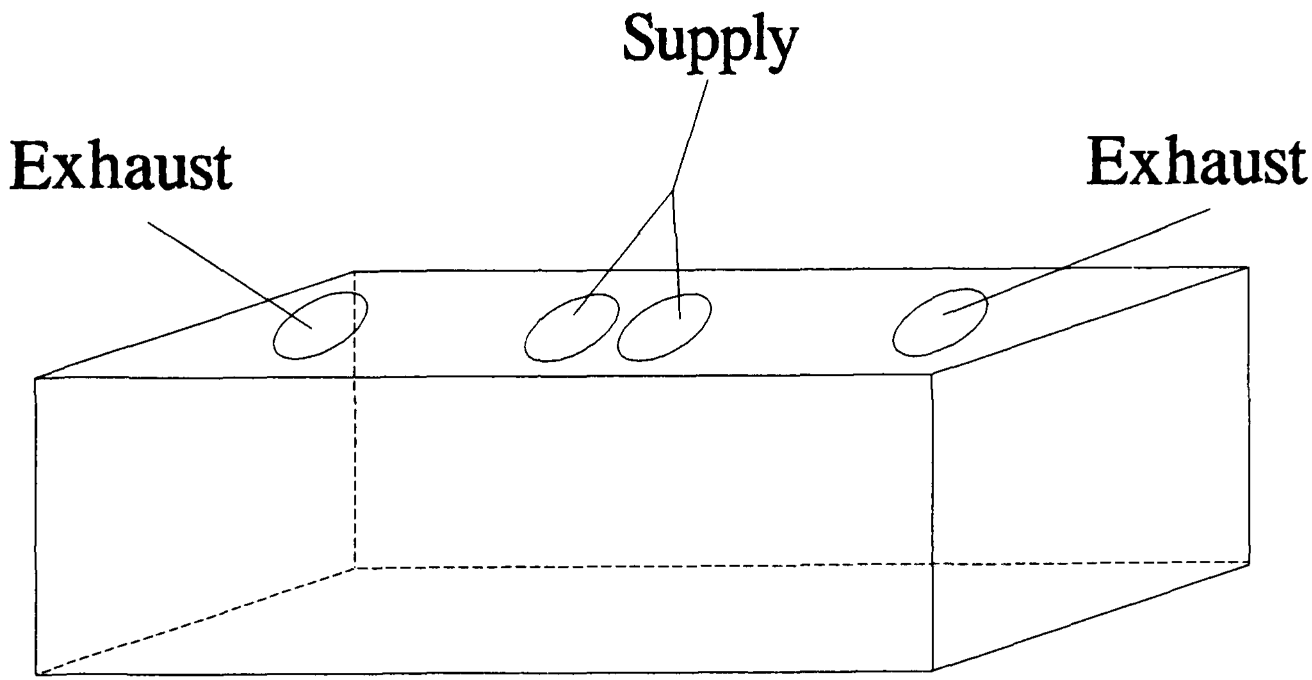


Figure 1. Fuel Tank

intrinsically safe blowers and a Class 2 flameproof particulate filter. Filter installation may cause a problem with tank ventilation flow rates. The increased filter resistance will decrease the exhaust flow rate, thereby causing an imbalance between supply and exhaust air flow. We recommend you let your Civil Engineering ventilation experts design a balanced system for you.

NOTE: All accessible openings are covered on the tank being sprayed.

Sealant Materials and Chemistry

1. Solvent Wipe Down: Turco 6628

    a) Principal Ingredients - toluene, ethyl acetate, MEK

    b) Material is used as received and is not diluted

2. Primer: 3 Part Epoxy Primer from DeSoto

    a) 519X303 - Primer Base

    b) 910X357 - Activator

    c) 020X324 - Solvent Reducer (Not used in this process)

The primer is mixed just prior to application with a ratio of three parts Primer Base to one part Activator. The hazard from this material can be broken into two fundamentally different types. First, there is an explosive hazard from the major solvent components, i.e., MEK, n-butyl acetate, and toluene, being sprayed in a confined space. Second, there may be possible health effects due to exposure to strontium chromate and toluene diisocyanate monomer (TDI). It is important to note, however, that these latter two constituents present only an airborne particulate hazard because of their lack of volatility. Therefore, they only present a hazard to personnel directly exposed to the paint spray mist; i.e., only to personnel spraying inside the fuel tank.

3. Sealant: 2-Part Polyamine Curing Agent Compound from PRC.

    a) PRC 2911 Part A - Activator. Principal Ingredients - diethyltoluenediamine (DETDA) and 1-methoxy-2-propanol acetate (PM Acetate)

    b) PRC 2911 Part B - Sealant Base. Principal Ingredients - PM Acetate, methylene bis(4-cyclohexyl isocyanate)(HMDI), and HMDI polythioether pre-polymer

The sealant is mixed just prior to application using a hand-held pneumatic mixer with a one-to-one ratio between parts A and B. Again, mixing changes the constituent concentrations from what is indicated in the MSDS to 50% PM Acetate, 40% HMDI polythioether pre-polymer (according to John Zook, PRC chemist, only 2.5% of the 40% is unreacted HMDI terminal groups), 2.5% HMDI monomer, 2.5% DETDA, and 5% pigment. The explosive hazard during sealant spraying is significantly reduced compared to the primer because PM Acetate is much less volatile. As with the primer application, most worker exposure to these materials will occur during spraying and only within the confined spaces of the tank. This proximal effect is due to the non-volatile nature of the contaminants which generate a particulate aerosol hazard only. Refer to Appendix A for a diagram of the vulcanization mechanism.

Personal Protective Equipment (PPE)

PPE, worn by workers to protect them from a hazardous work environment, is used while engineering controls are being developed or when appropriate engineering controls are still unable to adequately eliminate the hazard. It is NEVER used in place of engineering controls. In this particular case, PPE is used to supplement existing engineering controls to reduce the workers' risk. There are really three different exposure groups within Hangar 251: the sealant mixing operator, the sealant spray applicators and workers not associated with the sealant operation. All require different levels of protection. The last group has no exposure to the material and, therefore, does not require any PPE. Current procedures require the mixer to wear a full-face dual cartridge organic-vapor respirator, cotton coveralls with a polyethylene-coated Tyvek suit including boots and drawstring hood on top, and Ansell/Edmont nitrile gloves. All openings in this ensemble must be taped to prevent any skin exposures. A portable ventilation booth is being procured for mixing operations. Current procedures require the sealant applicators to wear full-face, positive-pressure, air-supplied respirators, cotton coveralls with a Sarnex 23P suit including boots and drawstring hood on top, and Ansell/Edmont nitrile gloves. Again, all openings must be taped to prevent skin exposures. Heat stress became a problem for the personnel inside the tank; consequently, a whole-body cooling suit system was procured and seems to work very well. The method of operation is very simple. A small pumping unit circulates ice water within narrow plastic tubing woven throughout a cotton suit.

Confined Space Entry

According to the proposed Occupational Safety and Health Administration (OSHA) standard, Title 29 of the Code of Federal

Regulations (CFR) Part 1910.146, the F-111 fuel tank must be considered a confined space. However, the new AFOSH Std. 127-25 governing confined space entry specifically excludes fuel cells. Volume 54, Number 106 page 24102-24110 of the Federal Register contains the proposed rules and defines a "permit required confined space" as an enclosed space which:

1. Is large enough and so configured that an employee can bodily enter and perform assigned work.

2. Has limited or restricted means for entry or exit.

3. Is not designed for continuous employee occupancy; and,

4. Has one or more of the following characteristics:

    a. Contains or has a known potential to contain a hazardous atmosphere.

    b. Contains a material with the potential for engulfment of an entrant.

    c. Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls, or a floor which slopes downward and tapers to a smaller cross-section; or,

    d. Contains any other recognized serious safety or health hazard.

Thus, according to the OSHA definition, the tank should be considered a "permit required confined space." On page 24103 of the proposed rule OSHA, sets forth the entry permit program as:

1. Hazard Identification

2. Hazard Control

3. Permit System - Requirements set forth in 1910.146 (d) pg 24103.

4. Employee Information

5. Prevention of Unauthorized Entry

6. Employee Training - Requirements set forth in 1910.146 (e), (f), and (g) pg 24104.

7. Equipment

8. Rescue - Requirements set forth in 1910.146 (h) pg 24105.

9. Protection from External Hazards

10. Duty to Other Employees

Waste Stream Discharge

All of the material exhausted by the ventilation system is vented through the roof directly outside. Due to the composition of the material being sprayed, even without a filter, only the solvents would actually be discharged to the outside air. The Environmental Management Division at McClellan AFB has stated that, at the current usage levels, the mass of volatile organic chemicals (VOC) does not violate current California State Regulations. Again, we highly recommend use of an in-line particulate filter.

POTENTIAL HAZARDS

The solvents in the material combined with the confined space of the fuel tank produce an explosive hazard during spray application.

The strontium chromate contains hexavalent (Cr+6) chromium which is listed as a human carcinogen by the International Agency for Research on Cancer and the National Toxicology Program and as a potential human carcinogen by the American Conference of Governmental Industrial Hygienists (ACGIH). The Cr+6 form is treated differently than the trivalent (Cr+3) form because Cr+6 is readily absorbed by the body while Cr+3 is not. An ironic point to note is the damage to the body is caused by the reduction of Cr+6 to Cr+3.

Between the primer and sealant material, three different forms of isocyanates are used: Toluene diisocyanates (TDI), HMDI, and HMDI polythioether pre-polymer. The hazard stems from the extreme reactivity of the isocyanate functional group (N=C=O). Isocyanates are doubly dangerous because they will readily react with the moisture in the skin as well as any of the mucous membranes. They are potent sensitizers and once sensitized, exposure to levels far below the threshold limit value (TLV) will still elicit a reaction. Again, it is important to note that, because of the extremely low volatility of the isocyanates, they present an airborne particulate hazard to only those personnel exposed to the spray mist.

The sealant contains a secondary amine DETDA which activates the isocyanate and begins the vulcanization mechanism. The manufacturer, Ethyl Corporation, has performed a two-year study

on rats. It should be noted that two years represents a lifetime exposure in rats. Results indicate possible liver, thyroid, pancreas, kidney, and mammary gland effects at the highest dosing level. As with isocyanates, DETDA presents a skin contact hazard and has an extremely low vapor pressure. It requires skin protection and presents a particulate aerosol hazard only to personnel directly exposed to the spray mist.

The solvent used in the sealant, PM Acetate, is water soluble and will not cause defatting of the skin, a common solvent hazard. On the other hand, it has a unique, unpleasant odor which becomes noticeable between .1 and 1 ppm due to the acetate portion. The odor caused a "health awareness" problem with the general hangar population. This is a new odor to them, and they believe they are being "overexposed" to this chemical. The manufacturer, Dow Chemical, has conducted animal testing and recommends an exposure limit of 100 ppm. They note, however, that at concentrations of 80 ppm, no human would be able to stand the "terrible stench."

AIR SAMPLING STRATEGIES AND RESULTS

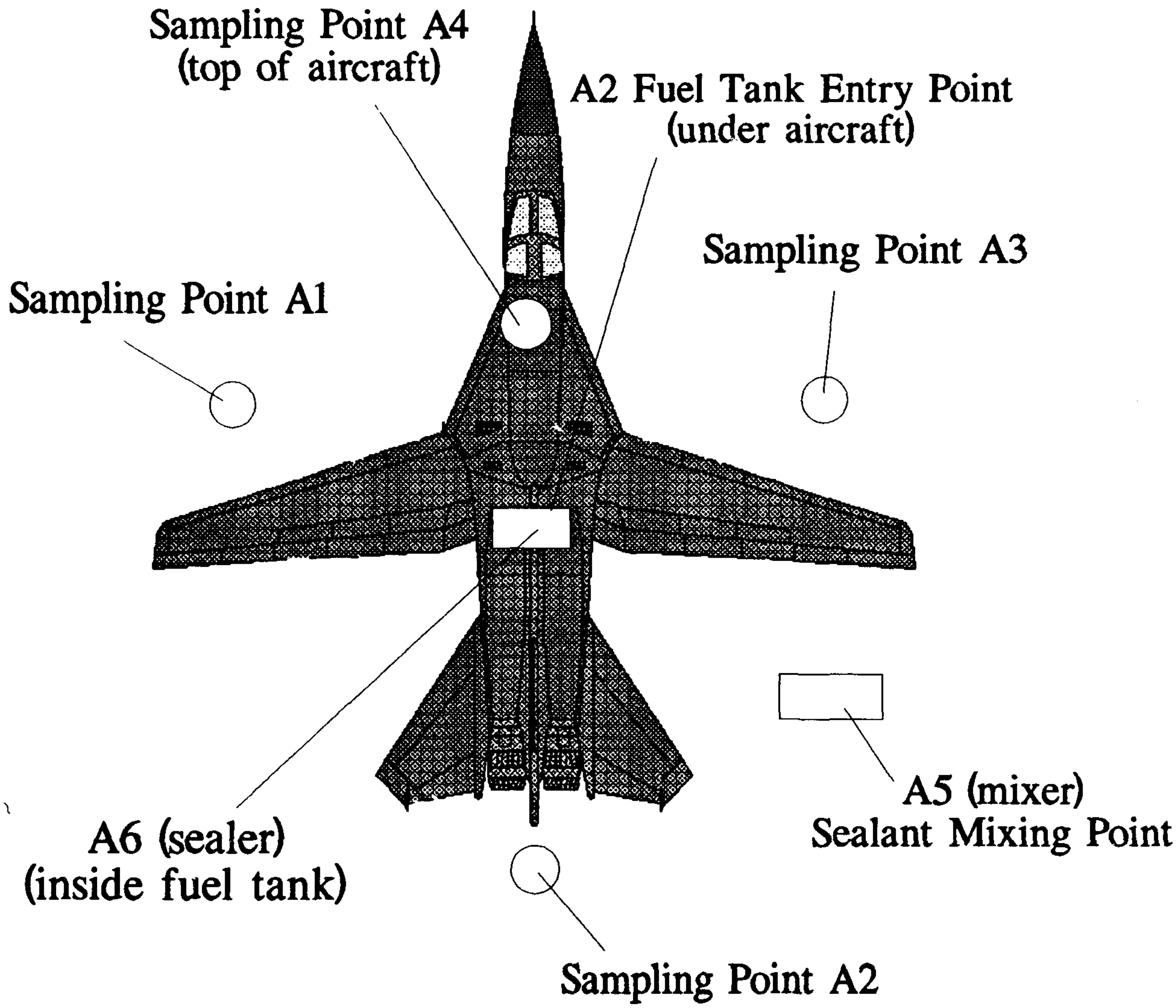
Many air samples were collected during the three different surveys. They were separated into three different categories to coincide with the three different exposure groups.

First, breathing zone samples were collected on the personnel spraying the sealant in the tank. Next, breathing zone samples and some general area samples were collected during the sealant mixing operation. Finally, general area samples were collected at varying distances from the aircraft being sprayed representing possible exposures to personnel not associated with the sealant process.

Appendix B contains all the tabulated sample results along with the most stringent exposure guidelines. The 15-min Time Weighted Average (TWA) values indicate worst-case exposures assuming all the contaminant is collected in the first 15 minutes of the sampling period. These values are then compared to the Short Term Exposure Limit (STEL). Figures 2-7 show all the sampling locations utilized. Note that no data is available for the sampling done by Lt Devine during September 1991.

Sample Results Within Tank

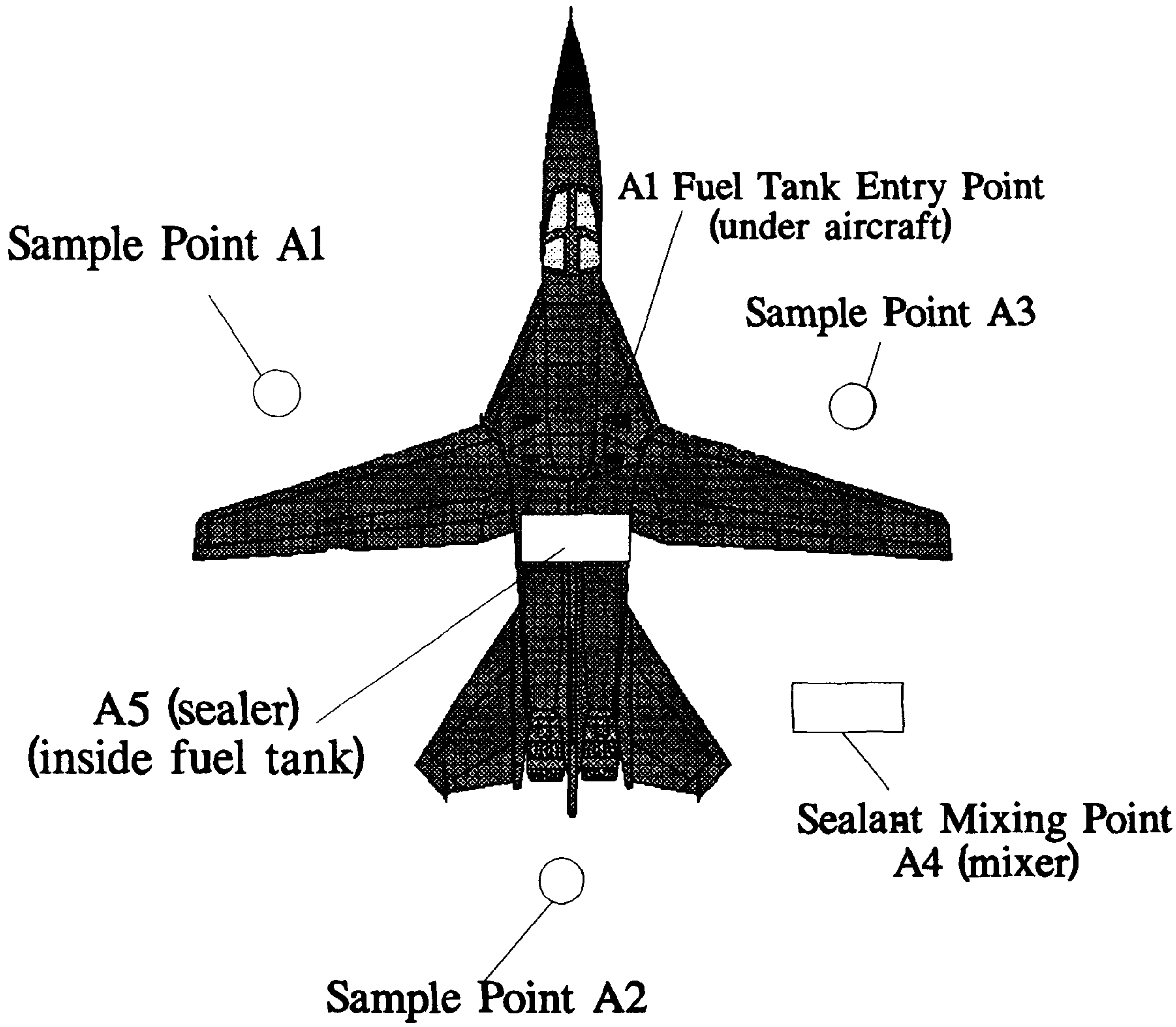
Solvent samples for the priming operation were only collected during the January 1991 survey. The highest exposures were for isopropyl alcohol and toluene. Neither compound's 8-hr TWA exceeded the TLV; however, isopropyl alcohol exceeded a worst case STEL by three times.



NOTE: All sampling points app. 17 ft from entry point

Figure 2. Sampling Points of F-111 Aircraft (not to scale)

22 Jan 91



NOTE: All sampling points app. 17 ft from entry point

Figure 3. Sampling Points of F-111 Aircraft (not to scale)

23 Jan 91

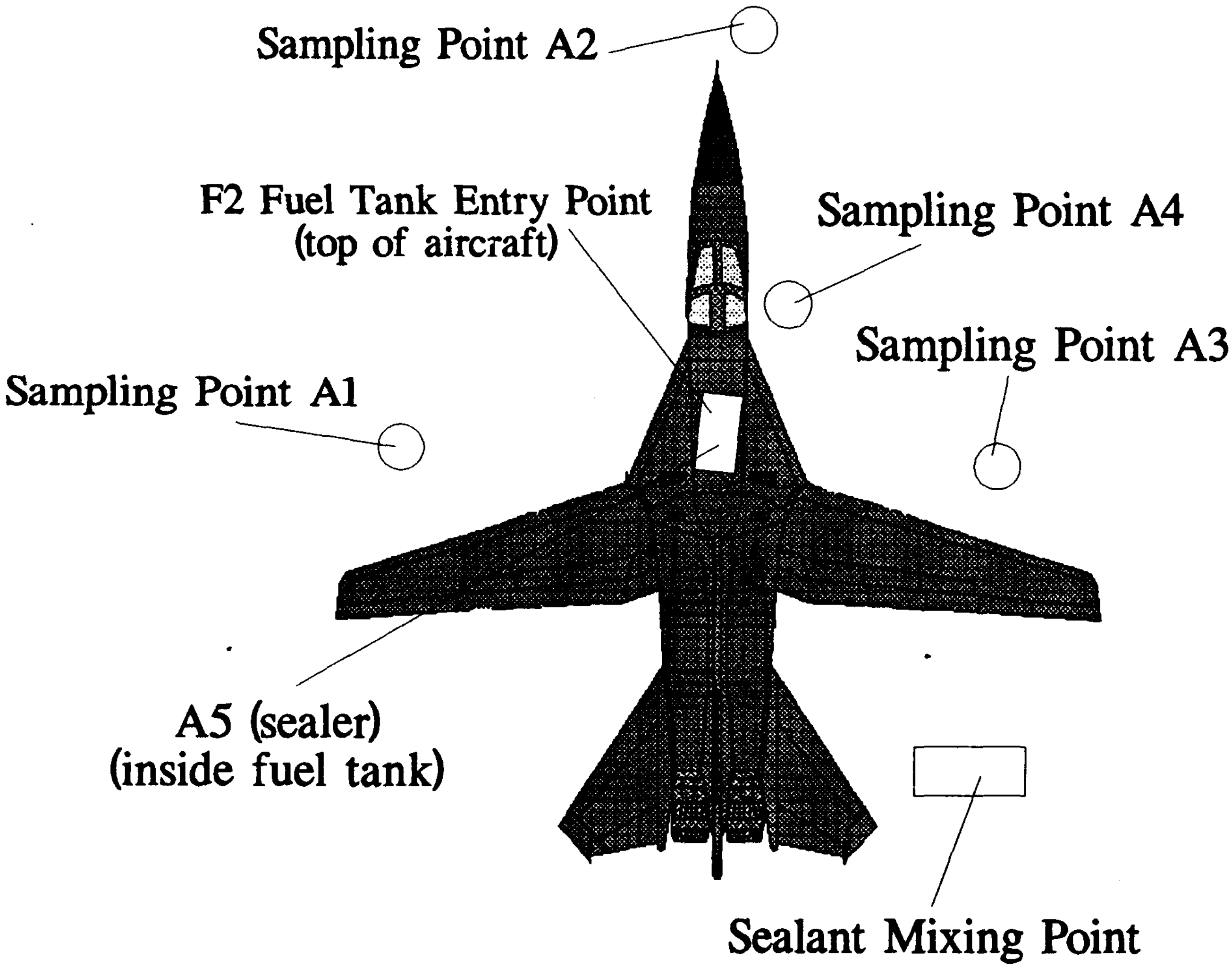


Figure 4. Sampling Points of F-111 Aircraft (not to scale)

24 Jan 91

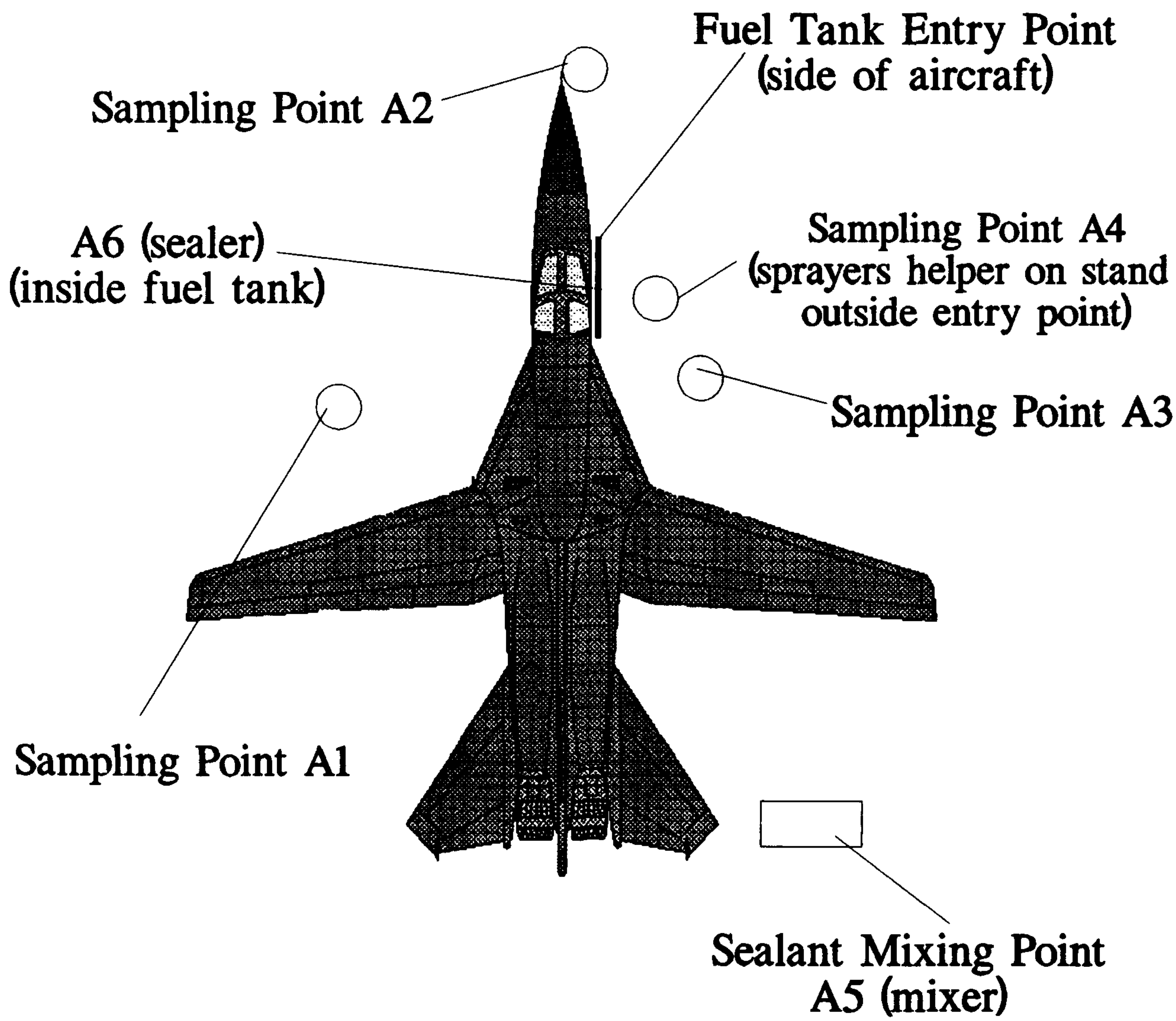
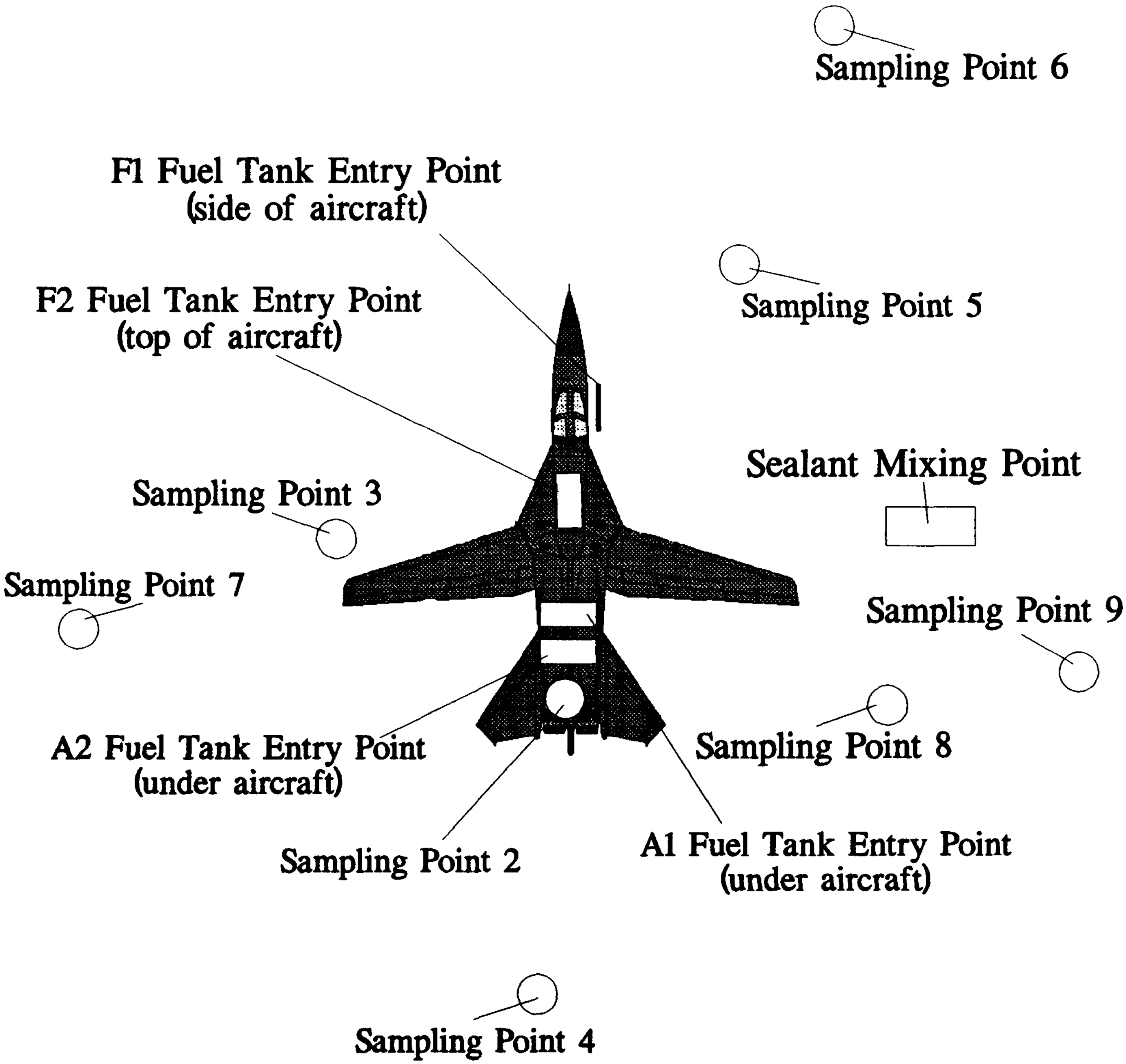


Figure 5. Sampling Points of F-111 Aircraft (not to scale)

25 Jan 91



NOTE: Sample Point 1
(sealer inside different
fuel tank each day)

Figure 6. Sampling Points of F-111 Aircraft (not to scale)
12 - 16 Aug 91

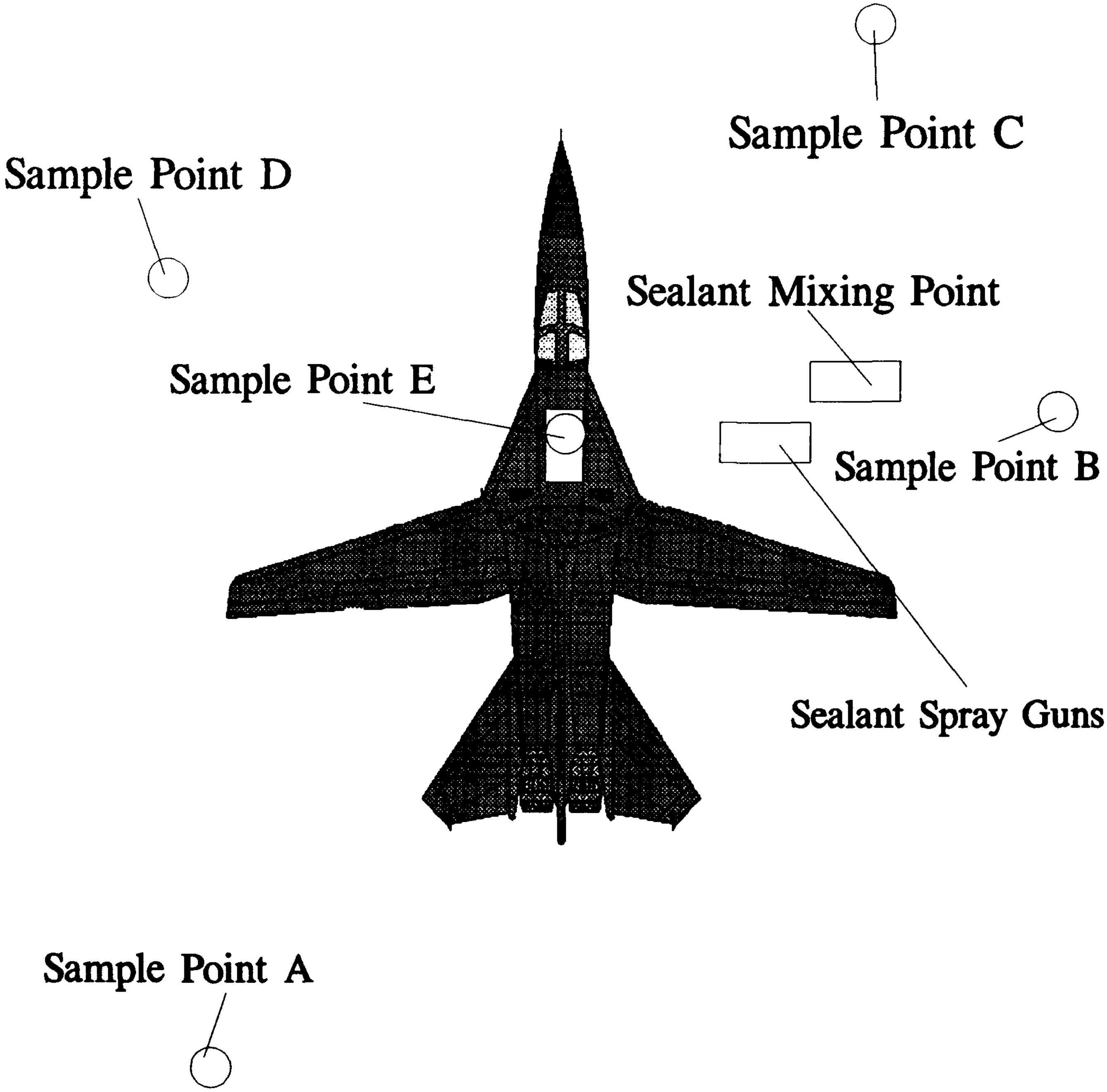


Figure 7. Sampling Points of F-111 Aircraft (not to scale)
30 Oct 91

Strontium chromate 8-hr TWA values exceeded the TLV by as much as 360 times during the January 1991 sampling and 680 times during the August 1991 sampling. It is important to note that the TLV for strontium chromate has changed since the survey was done. The TLV at the time of the sampling was 0.05 mg/m^3; the new TLV is 0.0005 mg/m^3. Consequently, not enough air volume was collected during the sampling and the detection limit of the analysis of these samples is above the TLV.

The August 1991 survey sample results indicate a worst case HMDI exposure that exceeded the TLV by 10.3 times. The DETDA and 1M2PA sample results are well below the manufacturer's recommended exposure limits. Although some of the above results seem very high, they originate within a confined space and personnel are wearing a positive pressure supplied respirator which provides a protection factor of 1000.

Sample Results From Mixing

Samples were collected on the mixer only during the Jan 91 survey and all results were below recommended exposure guidelines. However, due to the extreme sensitization characteristics of isocyanates and the close proximity to the ongoing operation, all mixing personnel should continue to wear the PPE previously described in the PPE section.

Sample Results Within Hangar

Sample collection points ranged from 13 to 120 feet from the aircraft being sprayed. During the January 1991 survey, several strontium chromate samples were above exposure limits. On 24 January, levels exceeding the TLV by 18 times were detected in location A4 (see Figure 4). On 25 January, levels exceeding 100 times the TLV were measured on the helper (see Figure 5). During the August 1991 survey, all general area samples were below detection limits. However, as noted above, due to the low sample volume collected, the TLV is below the analysis detection limit. These results indicate that, with the exception of strontium chromate at location A4, no airborne hazard exists outside the fuel tanks. The levels of air samples collected by Lt Devine for DETDA and 1M2PA were below the manufacturer's recommended exposure limits.

CONCLUSIONS

1. This process can be done efficiently and SAFELY!!

2. Odor does not mean there is a hazard!!

3. Exposures are classified into three different categories.

4. Exposures within the tank can be and are controlled with the use of current PPE and ventilation.

5. Results conclusively indicate, excepting strontium chromate, no exposures outside the tank.

RECOMMENDATIONS

1. Have a balanced tank ventilation system designed for this process. It must include a Class 2 flameproof particulate filter.

2. All accessible tank openings must be covered.

3. Keep the chemistry of the products consistent when mixing. Changes in material viscosity can increase misting or clogging.

4. Keep the spray gun pressure constant. Increased pressure will increase material misting.

5. PPE described in the process T.O. must always be worn. Do not deviate due to a shorter exposure duration. The helper must wear the same PPE as the sealer to protect against strontium chromate exposure.

6. When the proposed OSHA Confined Space Entry Rule becomes final, compliance is mandatory. Most of the requirements are administrative and are described in the rules.

7. Provide employee training and hazard communication.

8. Ensure current sealant utilization rates do not violate the current state regulations.

9. Fuel tanks should be monitored prior to entry and during the operation for oxygen and explosive levels.

10. SGPB should continue to conduct process surveys with air sampling at least annually.

APPENDIX A

VULCANIZATION MECHANISM

VULCANIZATION MECHANISM:

Reaction starts after Part A and B are mixed -

```
               O
              / \
(A)   R-C  -  C---R'             (Epoxy-Thioether Resin)
          +
(B)   H2N-<O>-R"-<O>-NH2         (Diamine)
                 |
                 v
    H-O <-------------- ISOCYANATE CAN REACT
     |                                     |
    R-C  -  C-R'                           |
            |                              |
           HN-<O>-R-<O>-NH2 <---------------
                     ^
                     |
                 EPOXY CAN REACT
```

NOTE: Amine opens Epoxide ring generating hydroxyls (-OH) which can react with Isocyanates which can also react with Amines.

APPENDIX B

AIR SAMPLE RESULTS

22 January 1991
Priming Operation

Sample # (*)	Location (**)	Contaminant Analysis	Result (mg/m3)	8-hr TWA (mg/m3)	TLV (mg/m3)@	15 min TWA (mg/m3)	STEL (mg/m3)
SX910001	A2	Str Chr	0.01	0.0013	0.0005		
SX910002	A2	TDI (TD)	0.042	0.006	0.036	0.042	0.14
SX910003	A2	Iso Alc	<1.2	<0.16	983	<1.2	565
SX910005	A3	Str Chr	<0.01	<0.0013	0.0005		
SX910007	A3	Iso Alc	<1.2	<0.16	983	<1.2	1230
SZ910010	A5 (mixer)	TDI (TD)	0.21	0.0025	0.036	0.021	0.14
SZ910011	A5 (mixer)	Iso Alc	<1.2	<0.16	983	<1.2	565
SZ910013	A6 (sealer)	Toluene	155	17.76	188		
SX910015	A4	Str Chr	0.08	0.002	0.0005		
SX910016	A4	TDI (TD)	0.063	0.0018	0.036	0.063	0.14
			1st Adhesive Coat				
SX910017	A1	HMDI (TD)	<0.01	<0.00028	0.054		
SX910018	A1	1M2PA	<0.91	<0.26	540	<0.91	2700
SX910019	A3	HMDI (TD)	0.57	0.016	0.054		
SX910020	A3	1M2PA	<0.93	<0.26	540	<0.93	2700
SZ910022	A5 (mixer)	HMDI (TD)	1.15	0.03	0.054		
SZ910023	A5 (mixer)	1M2PA	<0.92	<0.26	540	<0.92	2700
SZ910024	A6 (sealer)	HMDI (TD)	2.6	0.073	0.054		
SZ910026	A6 (sealer)	1M2PA	454	129	540	454	2700
SX910027	A4	HMDI (TD)	0.04	0.001	0.054		

23 January 1991
Priming Operation

Sample # (*)	Location (**)	Contaminant Analysis	Result (mg/m3)	8-hr TWA (mg/m3)	TLV (mg/m3)@	15 min TWA (mg/m3)	STEL (mg/m3)
SX910028	A1	TDI (TD)	1.6	0.0024	0.036	0.094	0.14
SX910029	A1	Str Chr	<0.07	<0.0018	0.0005		
SX910030	A1	Iso Alc	<1.2	<0.03	983	<1.25	1230
SX910032	A2	TDI (TD)	0.45	0.001	0.036	0.040	0.14
SX910033	A2	Str Chr	<0.07	<0.0018	0.0005		
SX910034	A2	Iso Alc	<1.2	<0.03	983	<1.2	1230
SX910036	A3	TDI (TD)	0.28	0.0006	0.036	0.025	0.14
SX910037	A3	Str Chr	<0.07	<0.0018	0.0005		
SX910038	A3	Iso Alc	<1.2	<0.03	983	<1.2	1230
SZ910040	A4 (mixer)	TDI (TD)	<0.01	0.00007	0.036	<0.001	0.14
SZ910042	A4 (mixer)	Iso Alc	26.8	2.0	983	26.8	1230
SZ910045	A5 (sealer)	Str Chr	4.3	0.18	0.0005		
SZ910046	A5 (sealer)	But Acetate	620	25.8	713	620	950
SZ910046	A5 (sealer)	Iso Alc	2980	124.2	983	2980	1230
SZ910046	A5 (sealer)	Toluene	695	29	188		
				1st Adhesive Coat			
SX910048	A1	HMDI (TD)	<0.01	<0.0003	0.054		
SX910049	A1	1M2PA	<1.0	<0.26	540	<1.0	2700
SX910050	A2	HMDI (TD)	<0.01	<0.0003	0.054		
SX910051	A2	1M2PA	<1.0	<0.26	540	<1.0	2700
SX910052	A3	HMDI (TD)	<0.01	<0.0003	0.054		
SX910053	A3	1M2PA	<1.0	<0.26	540	<1.0	2700
SZ910054	A4 (mixer)	HMDI (TD)	<0.01	<0.0003	0.054		
SZ910056	A4 (mixer)	1M2PA	<1.1	<0.27	540	<1.1	2700
SZ910058	A5 (sealer)	HMDI (TD)	<0.01	<0.0003	0.054		
SZ910059	A5 (sealer)	1M2PA	1658	432	540	1658	2700

24 January 1991
Priming Operation

Sample # (*)	Location (**)	Contaminant Analysis	Result (mg/m3)	8-hr TWA (mg/m3)	TLV (mg/m3)@	15 min TWA (mg/m3)	STEL (mg/m3)
SX910060	A1	Str Chr	<0.01	<0.0013	0.0005		
SX910061	A1	TDI (TD)	<0.01	<0.0013	0.036	<0.001	0.14
SX910062	A1	Iso Alc	<1.2	<0.15	983	<1.2	1230
SX910063	A2	Str Chr	<0.01	<0.0013	0.0005		
SX910064	A2	TDI (TD)	<0.01	<0.0013	0.036	<0.001	0.14
SX910065	A2	Iso Alc	<1.2	<0.15	983	<1.2	1230
SX910066	A3	Str Chr	<0.01	<0.0013	0.0005		
SX910068	A3	Iso Alc	<1.2	<0.15	983	<1.2	1230
SX910069	A4	Str Chr	0.09	0.0094	0.0005		
SX910070	A4	Str Chr	<0.03	<0.0031	0.0005		
SZ910071	A5 (sealer)	Str Chr	1.3	0.12	0.0005		
SZ910073	A5 (sealer)	But Acetate	824	81	713	824	950
SZ910073	A5 (sealer)	Iso Alc	3678	360	983	3678	1230
SZ910073	A5 (sealer)	Toluene	937	92	188		

1st Coat Adhesive

Sample # (*)	Location (**)	Contaminant Analysis	Result (mg/m3)	8-hr TWA (mg/m3)	TLV (mg/m3)@	15 min TWA (mg/m3)	STEL (mg/m3)
SX910075	A1	HMDI (TD)	<0.01	<0.0003	0.054		
SX910076	A1	1M2PA	<0.77	<0.26	540	<0.77	2700
SX910077	A2	HMDI (TD)	<0.01	<0.0003	0.054		
SX910078	A2	1M2PA	<0.77	<0.26	540	<0.77	2700
SX910079	A3	HMDI (TD)	<0.01	<0.0003	0.054		
SX910080	A3	1M2PA	<0.77	<0.26	540	<0.77	2700
SX910081	A4	HMDI (TD)	<0.01	<0.0003	0.054		
SZ910082	A5 (sealer)	HMDI (TD)	<0.01	<0.0003	0.054		
SZ910084	A5 (sealer)	1M2PA	814	270	540	814	2700

25 January 1991
Priming Operation

Sample # (*)	Location (**)	Contaminant Analysis	Result (mg/m3)	8-hr TWA (mg/m3)	TLV (mg/m3)@	15 min TWA (mg/m3)	STEL (mg/m3)
SX910085	A1	TDI (TD)	<0.01	<0.0001	0.036	<0.001	0.14
SX910086	A1	Iso Alc	<1.2	<0.165	983	<1.2	1230
SX910087	A2	TDI (TD)	<0.01	<0.0001	0.036	<0.001	0.14
SX910088	A2	Iso Alc	<1.2	<0.165	983	<1.2	1230
SX910089	A3	TDI (TD)	<0.01	<0.0001	0.036	<0.001	0.14
SX910090	A3	Iso Alc	<1.2	<0.165	983	<1.2	1230
SZ910091	A4 (helper)	Str Chr	0.70	0.05	0.0005		
SZ910092	A4 (helper)	But Acetate	114	9.98	713	114	950
SZ910092	A4 (helper)	Iso Alc	548	48	983	548	1230
SZ910092	A4 (helper)	Toluene	128	11.2	188		
SZ910093	A5 (mixer)	TDI (TD)	<0.01	<0.0001	0.036	<.001	0.14
SZ910095	A5 (mixer)	Toluene	8.7	0.40	188		
SZ910096	A6 (sealer)	Str Chr	1.1	0.08	0.0005		
SZ910098	A6 (sealer)	But Acetate	182	15.9	713	182	950
SZ910098	A6 (sealer)	Iso Alc	817	71.5	983	817	1230
SZ910098	A6 (sealer)	Toluene	316	27.7	188		

1st Coat Adhesive

Sample # (*)	Location (**)	Contaminant Analysis	Result (mg/m3)	8-hr TWA (mg/m3)	TLV (mg/m3)@	15 min TWA (mg/m3)	STEL (mg/m3)
SX910099	A1	HMDI (TD)	<0.01	<0.0004	0.054		
SX910100	A1	1M2PA	<0.61	<0.26	540	<0.61	2700
SX910101	A2	HMDI (TD)	<0.01	<0.0004	0.054		
SX910102	A2	1M2PA	<0.62	<0.26	540	<0.62	2700
SX910103	A3	HMDI (TD)	<0.01	<0.0004	0.054		
SX910104	A3	1M2PA	<0.61	<0.26	540	<0.61	2700
SZ910106	A4 (helper)	1M2PA	127	45.8	540	127	2700
SZ910107	A5 (mixer)	HMDI (TD)	<0.01	<0.0004	0.054		
SZ910109	A5 (mixer)	1M2PA	13.2	6.2	540	13.2	2700
SZ910110	A6 (sealer)	HMDI (TD)	0.63	0.022	0.054		
SZ910112	A6 (sealer)	1M2PA	1035	390	540	1035	2700
SZ910114	A6 (sealer)	HMDI (TD)	0.8	0.03	0.054		

12 August 1991
Priming Operation

Sample # (*)	Location (**)	Contaminant Analysis	Result (mg/m3)	8-hr TWA (mg/m3)	TLV (mg/m3)@	15 min TWA (mg/m3)	STEL (mg/m3)
SZ911348	1 (sealer)	TDI (MI)	0.0054	0.00063	0.036	0.0054	0.14
SZ911349	1 (sealer)	Str Chr	1.62	0.19	0.0005		
SX911350	2	TDI (MI)	<0.0035	<0.00065	0.036	<0.0035	0.14
SX911351	2	Str Chr	<0.009	<0.0017	0.0005		
SX911352	3	TDI (MI)	<0.0036	<0.00066	0.036	<0.0036	0.14
SX911353	3	Str Chr	<0.005	<0.0009	0.0005		
SX911354	4	TDI (MI)	<0.0035	<0.00065	0.036	<.0035	0.14
SX911355	4	Str Chr	<0.005	<0.0009	0.0005		
SX911356	5	TDI (MI)	<0.0037	<0.00068	0.036	<0.0037	0.14
SX911357	5	Str Chr	<0.005	<0.0009	0.0005		
SX911358	6	TDI (MI)	<0.0036	<0.00066	0.036	<0.0036	0.14
SX911359	6	Str Chr	<0.005	<0.0009	0.0005		
SX911360	7	TDI (MI)	<0.0034	<0.00062	0.036	<0.0034	0.14
SX911361	7	Str Chr	<0.005	<0.0009	0.0005		
SX911362	8	TDI MI)	<0.0034	<0.00064	0.036	<0.0034	0.14
SX911363	8	Str Chr	<0.005	<0.0009	0.0005		
SX911364	9	TDI (MI)	<0.0035	<0.00066	0.036	<0.0035	0.14
SX911365	9	Str Chr	<0.005	<0.0009	0.0005		
SZ911366	1 (sealer)	TDI (MI)	<0.0084	<0.00063	0.036	<0.0084	0.14
SZ911367	1 (sealer)	Str Chr	0.43	0.03	0.0005		

Sealing Operation

Sample # (*)	Location (**)	Contaminant Analysis	Result (mg/m3)	8-hr TWA (mg/m3)	TLV (mg/m3)@	15 min TWA (mg/m3)	STEL (mg/m3)
SZ911368	1 (sealer)	HMDI (MI)	0.0235	0.00328	0.054		
SZ911369	1 (sealer)	HMDI (TD)	<0.08	<0.0011	0.054		
SZ911370	1 (sealer)	1M2PA	706	98.55	540	706	2700
SX911371	2	HMDI (MI)	<0.0087	<0.00257	0.054		
SX911372	2	1M2PA	<0.3	<0.89	540	<0.3	2700
SX911373	3	HMDI (MI)	<0.0092	<0.00267	0.054		
SX911374	3	1M2PA	<0.28	<0.082	540	<0.28	2700
SX911375	4	HMDI (MI)	<0.0085	<0.00258	0.054		
SX911376	4	1M2PA	<0.3	<0.09	540	<0.3	2700
SX911377	5	HMDI (MI)	<0.0091	<0.00273	0.054		
SX911378	5	1M2PA	<0.3	<0.09	540	<0.3	2700
SX911379	6	HMDI (MI)	<0.0088	<0.00264	0.054		
SX911380	6	1M2PA	<0.28	<0.084	540	<0.28	2700
SX911381	7	HMDI (MI)	<0.0087	<0.00248	0.054		
SX911382	7	1M2PA	<0.31	<0.088	540	<0.31	2700
Sample # (*)	Location (**)	Contaminant Analysis	Result (mg/m3)	8-hr TWA (mg/m3)	TLV (mg/m3)@	15 min TWA (mg/m3)	STEL (mg/m3)

SX911383	8	HMDI (MI)	<0.0088	<0.0026	0.054		
SX911384	8	1M2PA	<0.38	<0.11	540	<0.38	2700
SX911385	9	HMDI (MI)	<0.0088	<0.00264	0.054		
SX911386	9	1M2PA	<0.28	<0.084	540	<0.28	2700
SZ911387	1 (sealer)	HMDI (TD)	0.76	0.01	0.054		
				13 August 1991 Sealing Operation			
SZ911415	1 (sealer)	HMDI (TD)	18.75	0.32	0.054		
SZ911416	1 (sealer)	1M2PA	1219	216	540	1219	2700
SX911417	2	HMDI (MI)	<0.0127	<0.0025	0.054		
SX911418	2	1M2PA	<0.42	<0.08	540	<0.42	2700
SX911419	3	HMDI (MI)	<0.0127	<0.0025	0.054		
SX911420	3	1M2PA	<0.42	<0.08	540	<0.42	2700
SX911421	4	HMDI (MI)	<0.0127	<0.0025	0.054		
SX911422	4	1M2PA	<0.42	<0.08	540	<0.42	2700
SX911423	5	HMDI (MI)	<0.0127	<0.0025	0.054		
SX911424	5	1M2PA	<0.43	<0.08	540	<0.43	2700
SX911425	6	HMDI (MI)	<0.0127	<0.0025	0.054		
SX911426	6	1M2PA	<0.37	<0.08	540	<0.37	2700
SX911427	7	HMDI (MI)	<0.0127	<0.0025	0.054		
SX911428	7	1M2PA	<0.44	<0.08	540	<0.44	2700
SX911429	8	HMDI (MI)	<0.0127	<0.0025	0.054		
SX911430	8	1M2PA	<0.4	<0.08	540	<0.4	2700
SX911431	9	HMDI (MI)	<0.0127	<0.0025	0.054		
SX911432	9	1M2PA	<0.43	<0.08	540	<0.43	2700

14 August 1991
Priming Operation

Sample # (*)	Location (**)	Contaminant Analysis	Result (mg/m3)	8-hr TWA (mg/m3)	TLV (mg/m3)@	15 min TWA (mg/m3)	STEL (mg/m3)
SZ911433	1 (sealer)	TDI (MI)	0.0252	0.0031	0.036	0.0252	0.14
SZ911434	1 (sealer)	Str Chr	2.79	0.34	0.0005		
SX911435	2	TDI (MI)	<0.005	<0.0006	0.036	<0.005	0.14
SX911436	2	Str Chr	<0.007	<0.00085	0.0005		
SX911437	3	Str Chr	<0.007	<0.00085	0.0005		
SX911438	4	Str Chr	<0.005	<0.007	0.0005		
SX911439	5	TDI (MI)	<0.005	<0.0006	0.036	<0.005	0.14
SX911440	5	Str Chr	<0.007	<0.00085	0.0005		
SX911441	6	Str Chr	<0.007	<0.00085	0.0005		
SX911442	8	TDI (MI)	<0.005	<0.0006	0.036	<0.005	0.14
SX911443	8	Str Chr	<0.007	<0.00085	0.0005		
SX911444	9	Str Chr	<0.007	<0.00085	0.0005		
SX911445	Hangar Roof	TDI (MI)	<0.005	<0.0006	0.036	<0.005	0.14

Sealing Operation

SZ911449	1 (sealer)	HMDI (MI)	0.0442	0.00645	0.054		
SZ911451	1 (sealer)	1M2PA	597	87.1	540	597	2700

15 August 1991
Sealing Operation

SZ911452	1 (sealer)	HMDI (MI)	0.922	0.0941	0.054		
SZ911453	1 (sealer)	HMDI (TD)	55.21	0.56	0.054		
SZ911454	1 (sealer)	1M2PA	1159	118	540	1159	2700
SX911455	2	HMDI (MI)	<0.012	<0.00243	0.054		
SX911456	2	1M2PA	<0.86	<0.16	540	<0.86	2700
SX911457	5	HMDI (MI)	<0.012	<0.00243	0.054		
SX911458	5	1M2PA	<0.42	<0.081	540	<0.42	2700
SX911460	8	HMDI (MI)	<0.0123	<0.00243	0.054		
SX911461	8	1M2PA	<0.41	<0.081	540	<0.41	2700
SX911462	F1	HMDI (MI)	<0.0113	<0.00243	0.054		
SX911463	F1	HMDI (MI)	<0.0113	<0.00243	0.054		
SX911464	Hangar Roof	HMDI (MI)	<0.0118	<0.00243	0.054		
SX911465	Hangar Roof	1M2PA	<0.40	<0.081	540	<0.40	2700

16 August 1991
Priming Operation

Sample # (*)	Location (**)	Contaminant Analysis	Result (mg/m3)	8-hr TWA (mg/m3)	TLV (mg/m3)@	15 min TWA (mg/m3)	STEL (mg/m3)
SX911493	F1	TDI (MI)	<0.0023	<0.0006	0.036	<0.0023	0.14
SX911494	Hangar Roof	TDI (MI)	<0.0025	<0.0006	0.036	<0.0025	0.14
SX911495	Hangar Roof	Str Chr	<0.004	<0.001	0.0005		
SX911496	2	TDI (MI)	<0.0023	<0.0006	0.036	<0.0023	0.14
SX911497	2	Str Chr	<0.004	<0.001	0.0005		
SX911498	4	TDI (MI)	<0.0023	<0.0006	0.036	<0.0023	0.14
SX911499	4	Str Chr	<0.004	<0.001	0.0005		
SX911500	5	TDI (MI)	<0.0023	<0.0006	0.036	<0.0023	0.14
SX911501	5	Str Chr	<0.004	<0.001	0.0005		
SX911502	8	TDI (MI)	<0.0023	<0.0006	0.036	<0.0023	0.14
SX911503	8	Str Chr	<0.004	<0.001	0.0005		
SX911504	9	Str Chr	<0.004	<0.001	0.0005		

10 September 1991
Sealing Operation

SX911775	25 ft	1M2PA	<0.19	<0.08	540	<0.19	2700
SX911776	50 ft	1M2PA	<0.19	<0.08	540	<0.19	2700
SX911777	75 ft	1M2PA	<0.19	<0.08	540	<0.19	2700
SX911778	A1	1M2PA	28.2	12.6	540	28.2	2700
SX911779	A2	1M2PA	608	272	540	608	2700

11 September 1991
Sealing Operation

SX911775	25 ft	1M2PA	<0.18	<0.09	540	<0.18	2700
SX911776	50 ft	1M2PA	<0.18	<0.09	540	<0.18	2700
SX911777	75 ft	1M2PA	<0.18	<0.09	540	<0.18	2700
SX911778	A1	1M2PA	32.5	15.6	540	32.5	2700
SX911779	A2	1M2PA	487	238	540	487	2700

Sample # (*)	Location (**)	Contaminant Analysis	Result (mg/m3)	8-hr TWA (mg/m3)	TLV (mg/m3)@	15 min TWA (mg/m3)	STEL (mg/m3)
12 September 1991 Sealing Operation							
SX911775	25 ft	1M2PA	<0.17	<0.09	540	<0.17	2700
SX911776	50 ft	1M2PA	<0.17	<0.09	540	<0.17	2700
SX911777	75 ft	1M2PA	<0.18	<0.09	540	<0.18	2700
SX911778	A1	1M2PA	21.6	10.8	540	21.6	2700
SX911779	A2	1M2PA	503	252	540	503	2700
13 September 1991 Sealing Operation							
SX911775	25 ft	1M2PA	<0.17	<0.09	540	<0.17	2700
SX911776	50 ft	1M2PA	<0.17	<0.09	540	<0.17	2700
SX911777	75 ft	1M2PA	<0.18	<0.09	540	<0.18	2700
SX911778	A1	1M2PA	198	99	540	198	2700
SX911779	A2	1M2PA	621	311	540	621	2700
24 September 1991 Sealing Operation							
SX911841	inside F-1	DETDA	12 ppb	4.5 ppb	30000 ppb	12 ppb	150000 ppb
SX911842	exit F-1	DETDA	<2 ppb	<0.75 ppb	30000 ppb	<2 ppb	150000 ppb
SX911843	mix mach	DETDA	<2 ppb	<0.75 ppb	30000 ppb	<2 ppb	150000 ppb
SX911844	30 ft	DETDA	<2 ppb	<0.75 ppb	30000 ppb	<2 ppb	150000 ppb
SX911848	inside F-1	DETDA	15 ppb	5.63 ppb	30000 ppb	15 ppb	150000 ppb
SX911849	exit F-1	DETDA	<2 ppb	<0.75 ppb	30000 ppb	<2 ppb	150000 ppb
SX911850	mix mach	DETDA	<2 ppb	<0.75 ppb	30000 ppb	<2 ppb	150000 ppb
SX911851	30 ft	DETDA	<2 ppb	<0.75 ppb	30000 ppb	<2 ppb	150000 ppb
SX918887	exit F-2	DETDA	<2 ppb	<0.96 ppb	30000 ppb	<2 ppb	150000 ppb
SX911888	mix mach	DETDA	<2 ppb	<0.96 ppb	30000 ppb	<2 ppb	150000 ppb
SX911889	30 ft	DETDA	<2 ppb	<0.96 ppb	30000 ppb	<2 ppb	150000 ppb

30 October 1991
Sealing Operation

Sample # (*)	Location (**)	Contaminant Analysis	Result (mg/m3)	8-hr TWA (mg/m3)	TLV (mg/m3)@	15 min TWA (mg/m3)	STEL (mg/m3)
EX912064	A	1M2PA	<0.37	<0.18	540	<0.37	2700
EX912066	A	DETDA	<0.32	<0.15	30000 ppb	<0.32	150000 ppb
EX912067	B	1M2PA	<0.41	<0.20	540	<0.41	2700
EX912069	B	DETDA	<0.37	<0.18	30000 ppb	<0.37	150000 ppb
EX912070	C	1M2PA	<0.42	<0.20	540	<0.42	2700
EX912072	C	DETDA	<0.32	<0.15	30000 ppb	<0.32	150000 ppb
EX912073	D	1M2PA	<0.43	<0.20	540	<0.43	2700
EX912075	D	DETDA	<0.38	<0.18	30000 ppb	<0.38	150000 ppb
EZ912076	E	1M2PA	174	83	540	174	2700
EZ912078	E	DETDA	<0.45	<0.22	30000 ppb	<0.45	150000 ppb

* All sample numbers with X as the second number are area samples and with Z as the second number are personal samples.

** See attached maps of sampling points.

@ The ACGIH TLV is used for all chemicals with the following exceptions:
The manufacturer's recommended exposure limits are used for 1M2PA and DETDA

TD - Total Dust
MI - Midget Impinger

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